I. DEPARTMENT/AGENCY

Coastal Studies Institute, Louisiana State University, Baton Rouge, LA 70803
9 September 2003

II. PROJECT TITLE

An X-Band Ground Station for the State of Louisiana

III. PROJECT LEADERS

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IV. DESCRIPTION OF THE PROJECT

This project funded the acquisition of equipment and LSU facility modifications for a new state-of-the-art X-Band satellite ground station at the Louisiana State University Earth Scan Laboratory. The project encompassed several phases including: installation of a 4.4 m auto-tracking antenna on the roof of Howe-Russell Geoscience Complex; the installation of several computers for data reception, data framing, archiving, calibration and product generation; and the testing of these new hardware and software systems by Earth Scan Laboratory staff, faculty and students. The new X-band environmental satellite telemetry system gives Louisiana the capability of receiving and processing advanced direct broadcast, high resolution earth environmental information. The access to real-time satellite data and analysis capabilities provides a valuable information source to enhance emergency management, public safety, public health, economic development, resource management, research and education. The new satellite sensor data that we acquire include Terra-1 and Aqua-1 MODIS (Moderate Resolution Imaging Spectrometer), Oceansat-1 OCM (Ocean Color Monitor), Radarsat-1 SAR, and ERS-2 SAR. The SAR (Synethetic Aperture Radar) data provides advanced real-time all-weather day-night high resolution satellite measurements. The L and S band systems, previously established in the laboratory, provide NOAA AVHRR, ARGOS and TOVS, Orbview-2 SeaWiFS and GOES GVAR data streams.

V. POST IMPLEMENTATION REVIEW AND ASSESSMENT

A. Executive Summary of Findings

This project was funded in April 2000 and successfully completed in June 30, 2003. During this time frame we 1) located a site for antenna installation; 2) prepared the roof for the extra load of the antenna; 3) supervised installation of the 4.4m tracking antenna on the roof of Howe Russell 4) tested hardware and software systems and 5) developed atmospheric and oceanic products for emergency response, research and education. The system has been fully operational since

February 2002 when the malfunctioning antenna positioner was replaced. The processing software became fully functional on June 19, 2003.

The new X-Band system provides much more detailed measurements of the earth, oceans and atmosphere on a time-series basis with higher spatial, spectral and radiometric resolutions. The new higher resolution MODIS and OCM data are providing time-series "birds-eye" views of storms and hurricanes, atmospheric contaminants, water quality parameters such as suspended sediments and algal blooms along the coast and in the river diversion regions, and land use/cover patterns. Daily acquisitions of MODIS and OCM imagery are being processed over several regions of the Gulf of Mexico and can be viewed on the ESL web site (http://www.esl.lsu.edu). The data are already being used extensively by faculty and students in their research at LSU and in collaboration with Southern University and University of New Orleans. The new facility was featured in the Morning Advocate, the Science and Technology page, on June 9, 2002.

B. Accomplishments and Best Practices Identified

The LSU X-band satellite system installation was a huge success, although some minor equipment problems had to be resolved in its first year of operation. LSU was the 3rd US University to have an operational X-band system for MODIS satellite data. The processing of the all-weather, day-night SAR data is exceedingly complex and requires a tremendous amount of disk space. As a result of savings in the antenna installation, we were able to purchase additional equipment and to obtain a 2-year license for the Oceansat-1 OCM data, an Indian system that provides higher resolution ocean color data, for algal bloom detection, than any other satellite currently in operation. LSU has the only U.S. license for data acquisition over the central Gulf of Mexico. A rawinsonde data system was also purchased that is enabling validation of the satellite data in air pollution studies. The X-band system has helped to leverage funding from federal and state funding sources for research and environmental management. These include NASA, National Institute of Health, Minerals Management Service, U.S. Army Corps of Engineers, LA Dept. of Environmental Quality, and the LA Board of Regents. Some sample image products are included at the end of the text.

Additional Highlights:

- Hurricane and tropical storm surveillance: In combination with other sensors, the MODIS data were used to monitor developments and movements of T.S. Isidore and Hurricane Lili in the Gulf of Mexico and along the Mexican coastline (in collaboration with the Louisiana Office of Emergency Preparedness, NOAA and the Southern Regional Climate Center).

- MODIS data have been used for air quality assessments and feasibility studies for ozone, haze, aerosols, and fog (in collaboration with LA DEQ, Port of Lake Charles and Minerals Management Service)

- MODIS data have been used for fire detection and surveillance over Louisiana (in collaboration with Louisiana Office of Emergency Preparedness, Southern Regional Climate Center).

- MODIS data have been used to determine the cloud-top height and temperature over the Gulf of Mexico. The correlation between MODIS data and National Weather Service (NWS) traditional rawinsonde point measurements at Key West, Florida proved excellent and may be implemented in the future for operational use.

- MODIS data have been used to assess coastal circulation processes in support of oil spill response activities (in collaboration with NOAA HAZMAT and local industries)

- MODIS and OCM data have been used to study the movement of river waters and algal blooms that develop in Louisiana's river diversion projects including Caernarvon, Davis Pond, Lake Pontchartrain and the Atchafalaya region (in collaboration with LA DNR, the LSU PULSES project, Jefferson Parish Environmental, the NOAA Coastal Ocean Program and EPA)

- MODIS and OCM are being used to research marsh changes in coastal Louisiana (LSU graduate student project)

- MODIS and OCM are being used in feasibility studies to calibrate/validate numerical models of circulation, sediment transport and waves along the Louisiana coastline (Faculty at the LSU Department of Oceanography and Coastal Studies Institute).

- MODIS and OCM are being used to map and understand habitats of infectious diseases in Louisiana and the southeast U.S. (LSU Veterinary Science Dept.).

C. Benefits Achieved/Expected

The acquisition of this X-band system was essential for keeping pace with technological advances in satellite remote sensing of the environment. It has enabled LSU and the state of Louisiana to receive some of the most advanced satellite data for the surveillance and study of rapidly changing meteorological and oceanographic events and processes. In addition, future earth observing satellite systems will use X-band technology. Louisiana's timely acquisition of such a system provides opportunities for both faculty and students to be at the cutting-edge of research and technology. Specific benefits achieved with the MODIS and OCM sensors have been mentioned previously. The new capability for reception and processing of Synthetic Aperture Radar (SAR) data provides LSU with a unique data stream for a university ground station. The processing and interpretation of this data is an order of magnitude more complex than our other satellite data streams. The Coastal Studies Institute and Department of Oceanography and Coastal Sciences plan to hire a faculty member with expertise in microwave remote sensing, who can more effectively apply this new capability for research and emergency response activities. The SAR data can be used in any weather, day or night, thereby yielding a big advantage over other sensor, especially during heavy cloud cover conditions typical of

storm/hurricane events. SAR data has many potential uses, such as providing the areal extent of flooding during storm events and enabling the detection of oil in coastal waters for oil spill response activities.

D. Pitfalls Encountered

A few equipment problems were experienced with the X-band antenna. The main antenna problem was finally solved (February 2002) with the installation of a new antenna positioner. In addition, the software was delivered in several stages, making effective use of the data a challenge until June 2003. The annual software licenses (starting in January 2004) will significantly increase our operational expenses and we are searching for funding sources to help defray these new costs. It is essential that we locate a continuous funding source to cover these costs, approximately $25,000 per year. In addition, the Oceansat data access license expires in March 2004. Based on past prices, renewal of the license will be $15,000 per year. This data has tremendous value for Louisiana coastal research and surveillance, especially for water quality such as suspended sediment loads and algal blooms (some harmful).

E. Recommendations to Agencies Planning to Use This New Technology

The multi-spectral satellite imagery and measurements, acquired in real-time from 10 different satellites at the Earth Scan Laboratory, have wide-ranging applications for emergency response, public health, research and education. The data are received via antenna, archived, calibrated to geophysical units (temperature, reflectance, radiance), navigated, and registered using the Terascan software developed by SeaSpace Corporation. Although most of the data processing and analyses are performed with this proprietary software the derived satellite measurements can be provided in formats that are easily ingested into other analysis packages such as ERDAS Imagine, ARC-GIS, and MATLAB, for example.

We maintain a web site at LSU (http://www.esl.lsu.edu) where MODIS and OCM satellite imagery are viewable for several Gulf of Mexico coastal regions. Many of our products are updated daily and some are provided in quasi-real-time (within an hour of acquisition). We have also recently completed display capabilities via the web site to enable the user to predict into the future (9 days) as well as to hindcast satellite coverage (time, location) over particular areas of interest. This will be useful as an educational tool, for requesting data and for planning field measurement programs where satellite coverage is desirable.

VI. FINAL COST vs. BUDGET

(to be provided by authorized University Fiscal Agent)

VII. ITEMIZED LIST OF PROJECT EXPENSES

(to be provided by authorized University Fiscal Agent)

Figure 1. 4.4 m X-Band tracking antenna being installed on LSU campus in February 2001. Smaller L-band antenna dome is shown left of center. The white domes serve as an important protection against detrimental environmental factors for these two tracking antennae.

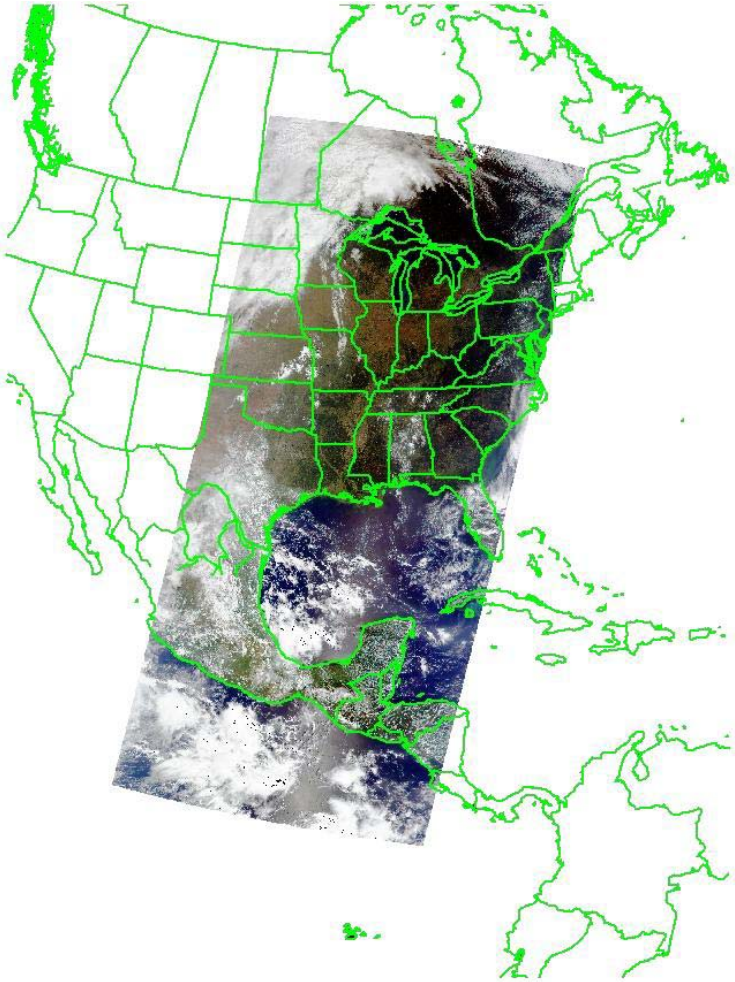

Figure 2. Example of an entire "swath" of MODIS (Moderate Resolution Imaging Spectrometer) data processed with RGB true color enhancement using channel 1 (250m), channel 4 (500m) and channel 3 (500m). MODIS has 36 channels of information. We capture at least 8 MODIS swaths each day. In the subsequent processing steps, geographic areas of interest are chosen to optimize the resolution of the data (see figures 3 and 4, as examples).

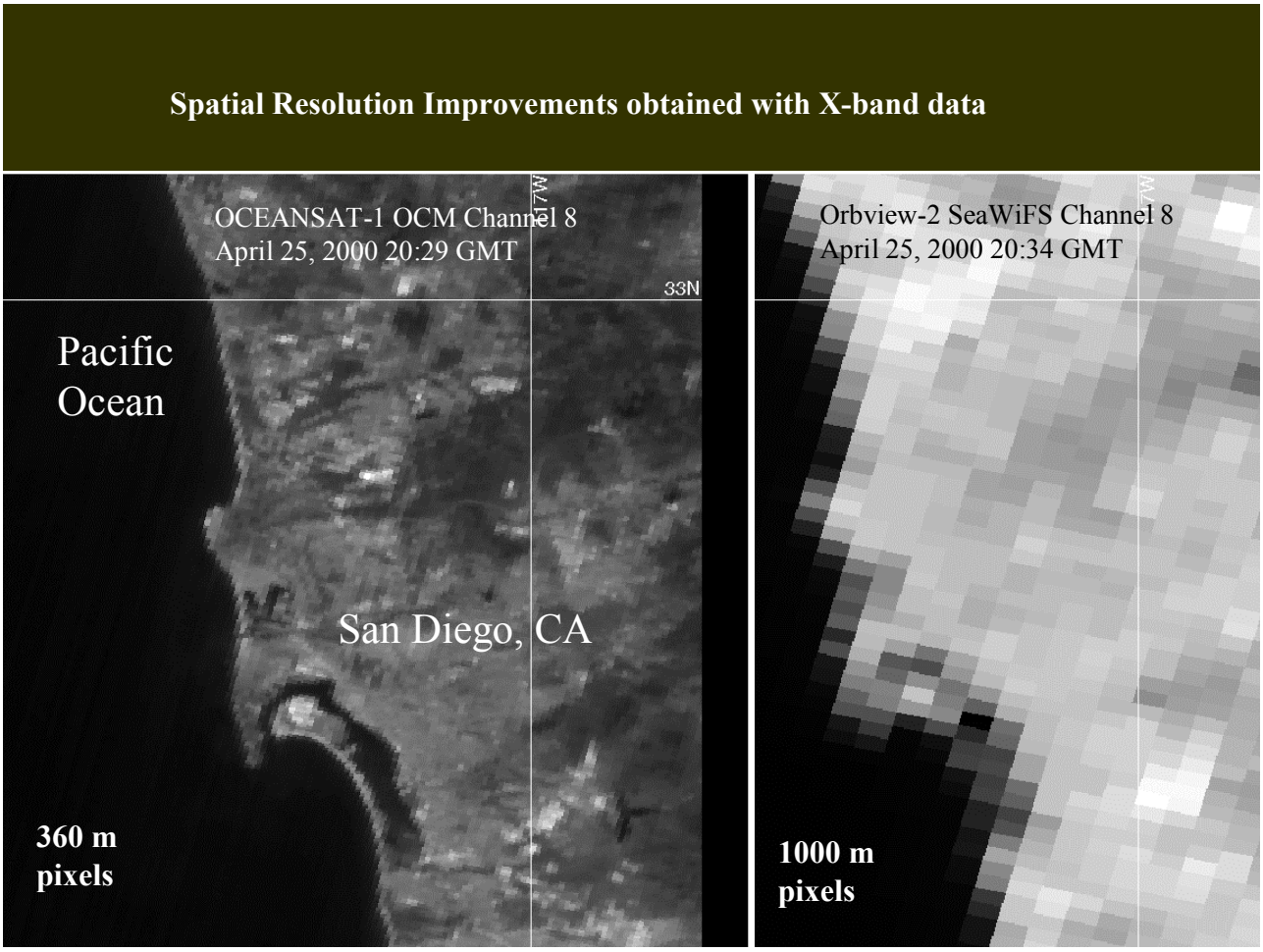

Figure 3. Comparison of the resolution of the ESL older technology L-band data (from SeaWiFS) with the new X-band data from Oceansat-1. Example is from San Diego, California.

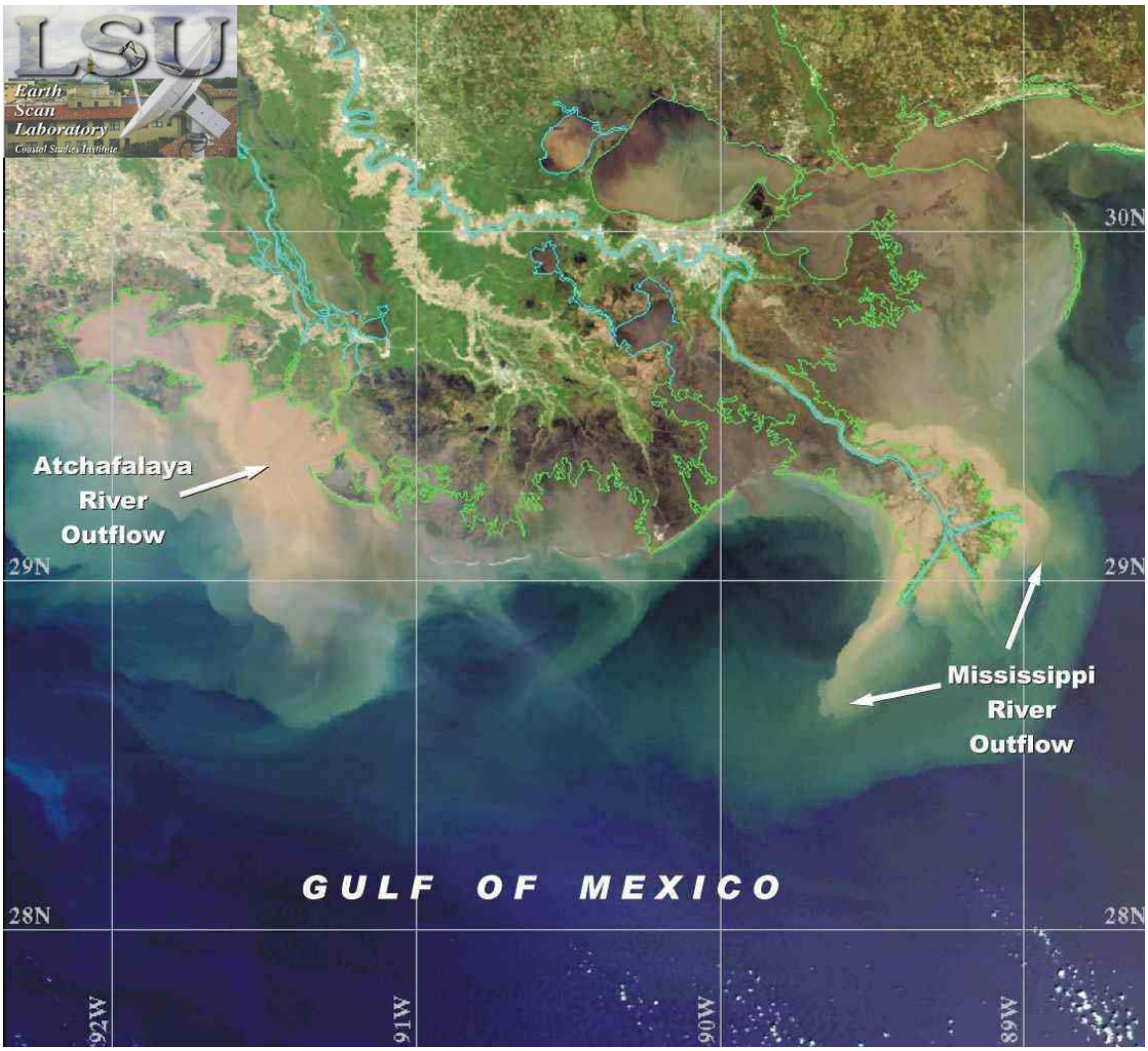

Figure 4. LSU Earth Scan Laboratory's first clear view of southern Louisiana land and water environments with the MODIS sensor on 21 February 2001. This "true color" enhancement using red, green and blue bands reveals vegetation patterns and river discharge along the Louisiana coast. These data are received by the X-band antenna daily.

Figure 5. "True color" RGB enhanced image (similar to Figure 4) showing an enlarged view of southeast Louisiana, depicting the spatial resolving power of the MODIS data that is accessible by the Earth Scan Lab equipment every day. Repeat coverage is essential for high frequency processes such as coastal circulation changes. River waters are depicted with the tan colors and marsh waters are dark due to the absorbing nature of tannic acids in the water. Water colors enable detection and tracking of unique water masses. River water is clearly apparent flowing through the Caernarvon diversion. A recent cold front passage event lowered coastal water levels which, in turn, accelerated the movement of river water into the Gulf.

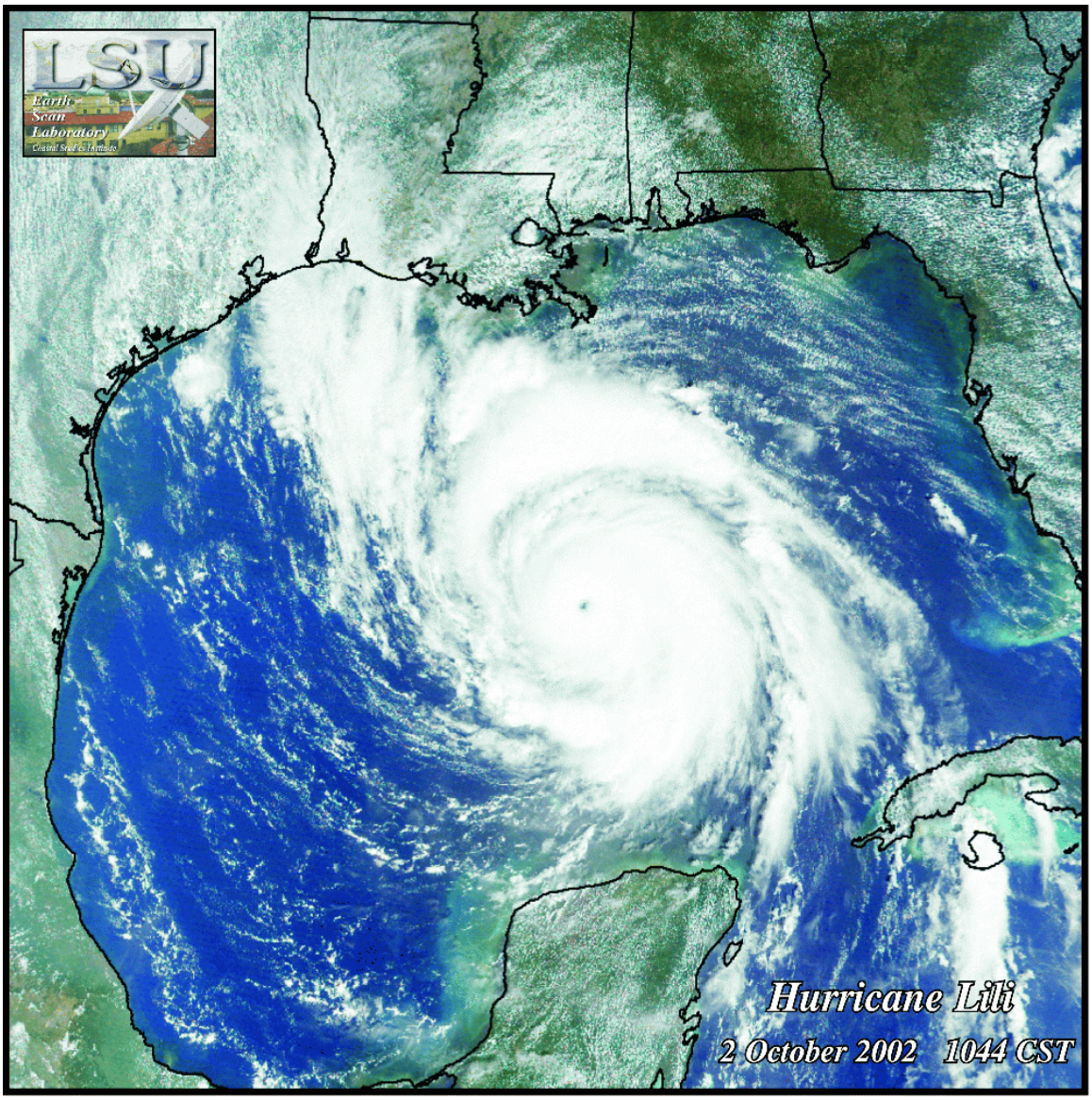

Figure 6. ESL MODIS RGB “true color” enhancement of Hurricane Lili on 2 October 2002.

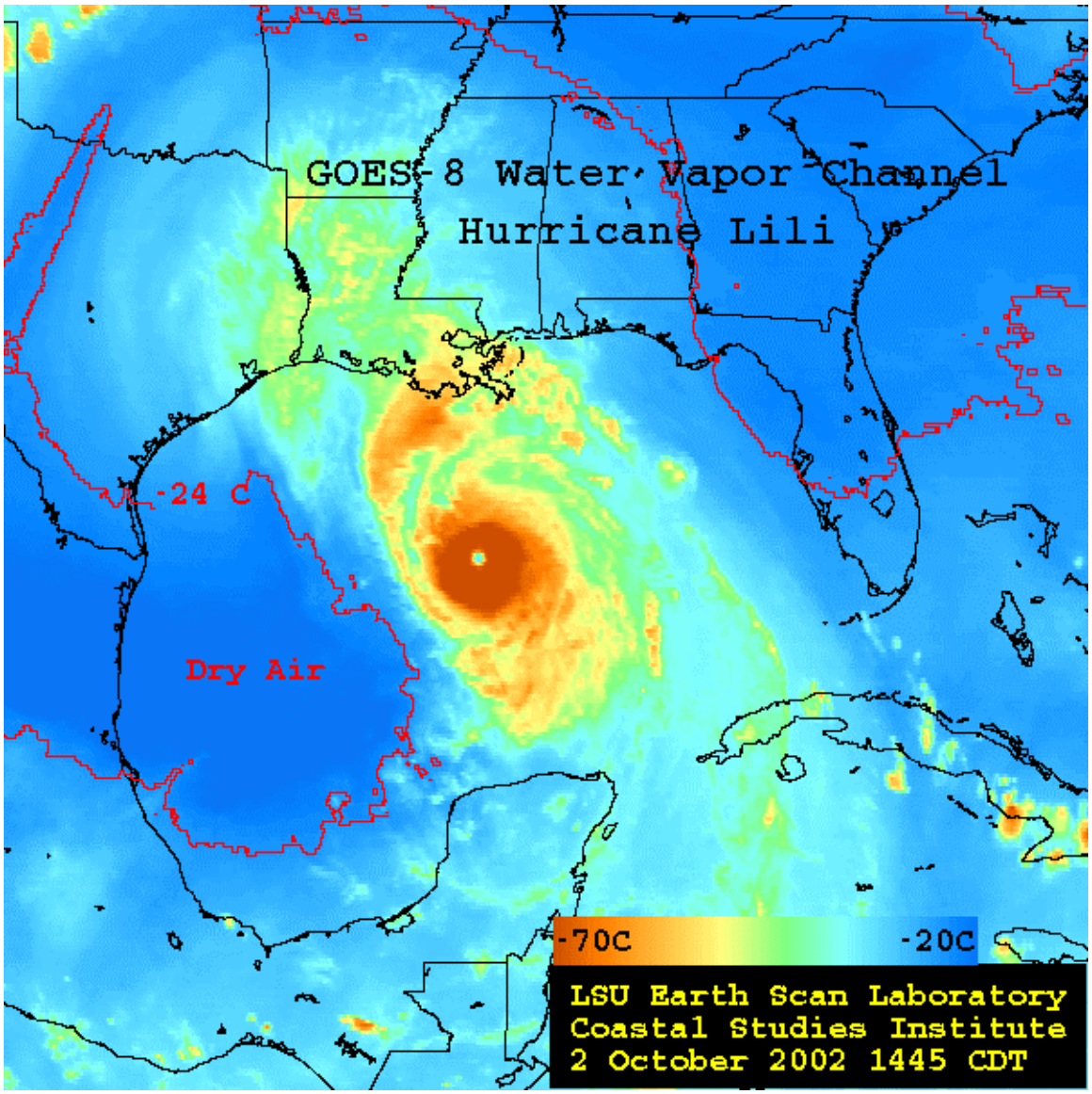

Figure 7. GOES-8 water vapor image of Hurricane Lili, showing the dry air mass that may have contributed to the sudden decrease in Lili's strength before hitting Louisiana on 4 October 2002. The GOES imagery is not X-band data and has a spatial resolution of 8 x 8 km. Nevertheless, the rapid repetition rate (every 15 minutes) makes it particularly useful for hurricane tracking activities.

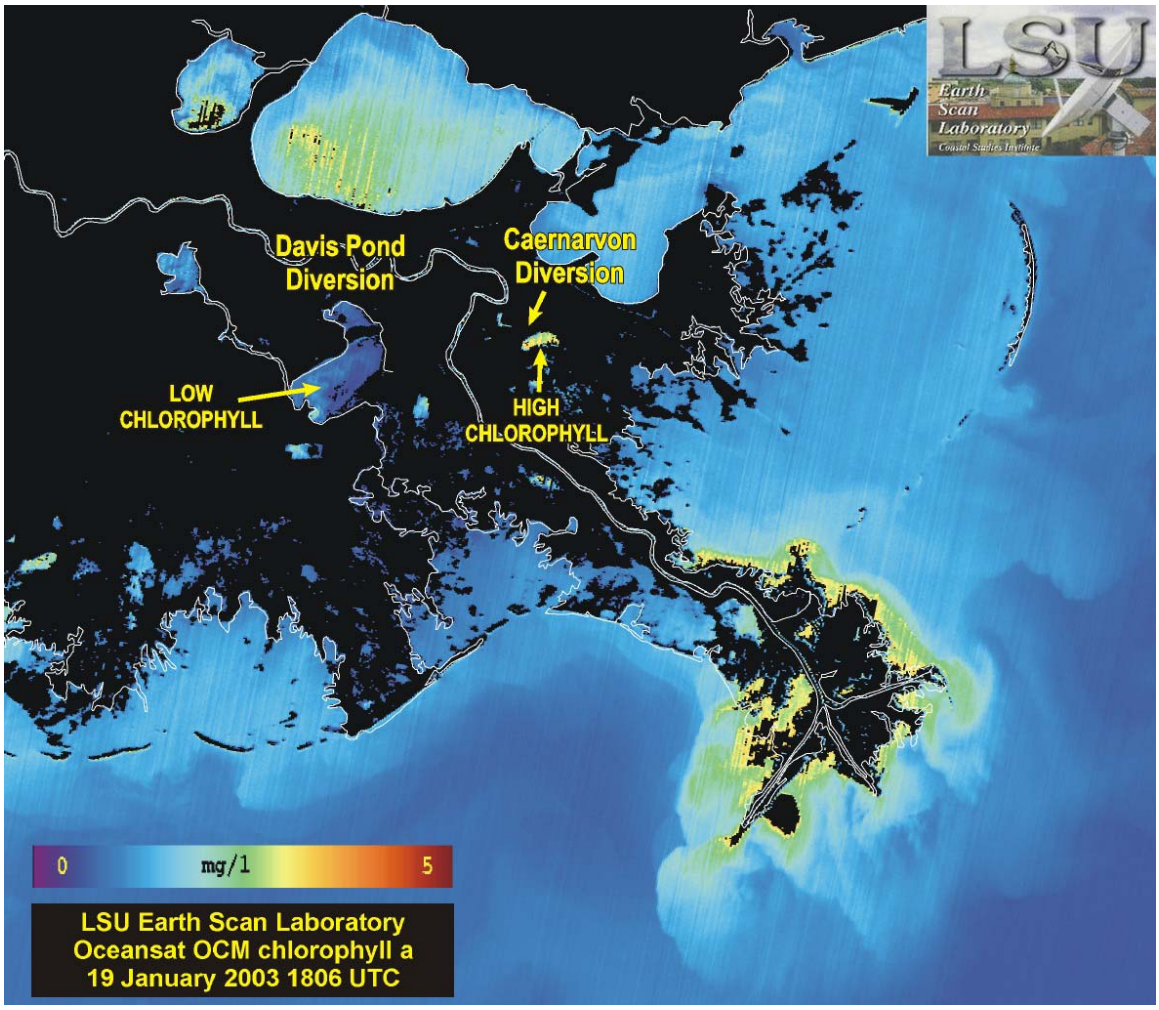

Figure 8. Oceansat Ocean Color Monitor satellite image acquired on 19 January 2003 with the LSU X-band antenna system and specially processed to reveal chlorophyll *a* in coastal and inland waters of southeast Louisiana. A 2-year license agreement with the Indian government has given us access to this data stream in real-time for research purposes. High chlorophyll levels were detected in areas receiving river water, including the Caernarvon diversion and the Mississippi River bird-foot delta region. The spatial resolution of this data is significantly better (10 times) than what is being obtained from the two NASA ocean color sensors, SeaWiFS and MODIS. Our experience with this data stream is that it is far superior than the other sensors for detecting chlorophyll both in coastal regions and in the GOM and the license should be continued, if financially feasible.

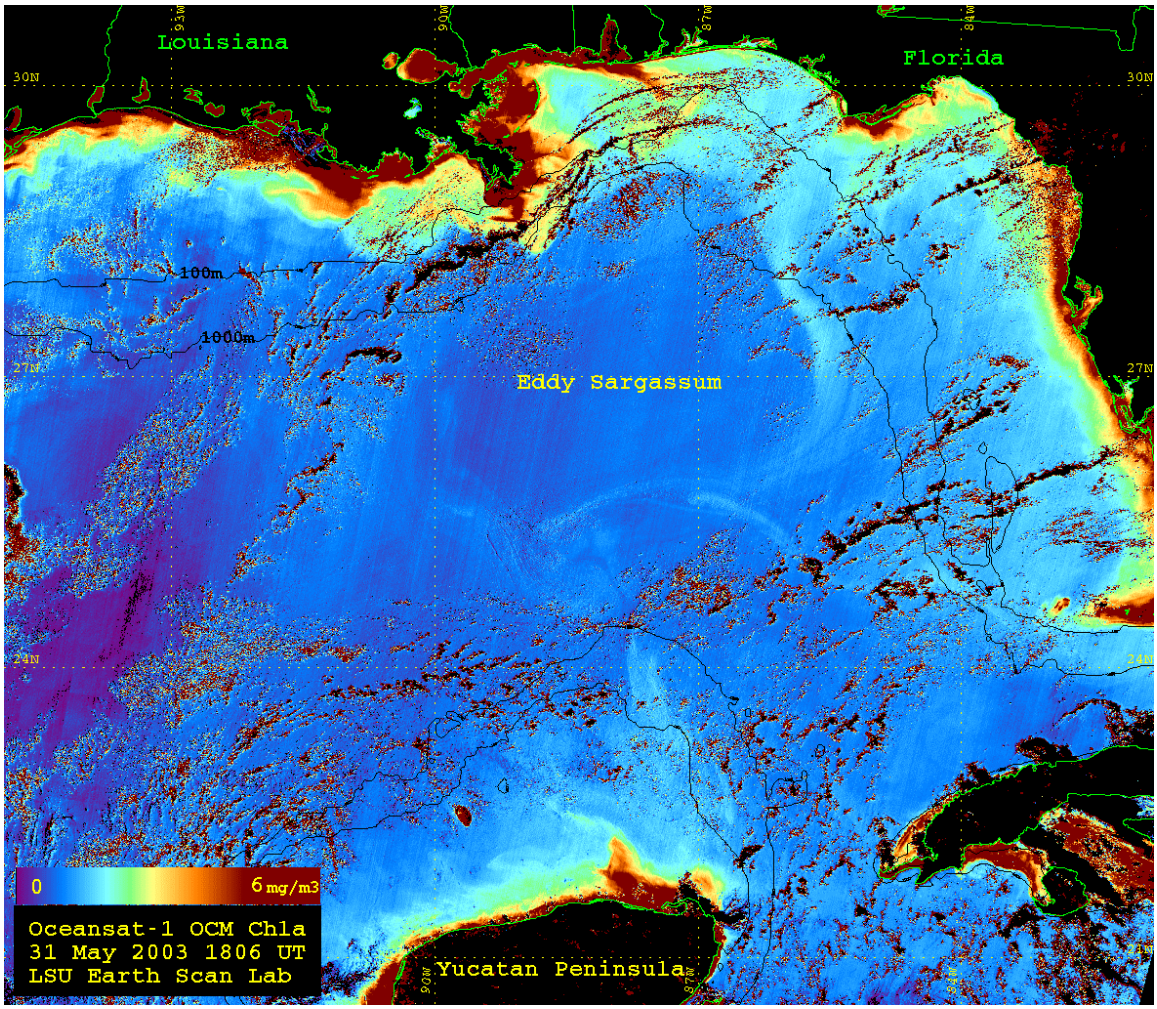

Figure 9. Oceansat Ocean Color Monitor satellite image acquired on 31 May 2003 with the LSU X-band antenna system and specially processed to reveal chlorophyll *a* in the relatively deep parts of the Gulf. This imagery has proven exceedingly useful for detecting the location and movement of large ocean eddies (such as Eddy Sargassum) that can impact negatively on the oil and gas industry. Black speckling is scattered clouds.

Figure 10. SAR image showing an abnormal flooding event (dark areas) near the Angola prison due to breaks in the levee of the Mississippi River. This type of high resolution data that "sees" through the clouds day or night is unique and has many applications for emergency response such as the mapping of flooded areas and detection/tracking of oil spills.